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MISCELLANEOUS COMMENTS AND OBSERVATIONS ON NAL 100 x 100 GeV COLLIDING BEAM STORAGE RING

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I. Background

A simple estimate of background in the neighborhood of a circulating beam is useful for appraising experimental problems. This method is due to Terwilliger and agrees within about x2 with measurements made by Hyams and Argoritsas near the circulating beam of the CERN p.s.

Assume: P gas collisions per cm

m average multiplicity

Pm secondaries per cm

$\phi_{\parallel} = Pm/2\pi\rho$; the flux of particles through unit area of a cylinder, radius ρ about beam

$\phi_{\perp} = \phi_{\parallel} / \tan\theta$ flux per unit area through disc normal to beam axis

$$\phi_{\perp} \approx \frac{Pm}{2\pi\rho\bar{\theta}}$$

$\bar{\theta} = p_{\perp} / \bar{p}_{\parallel}$ the average emission angel of secondaries

$\bar{p}_{\parallel} = p_o/m$ since $p_{\perp} \ll p_{\parallel}$; p_o is the beam momentum

$$\phi_{\perp} = \frac{Pp_o}{2\pi\rho\bar{p}_{\perp}} = \frac{Pp_o}{2\rho} \quad \text{since } p_{\perp} \cong 0.3 \text{ GeV/c.}$$

$$\boxed{\phi_{\perp} = 50P/\rho} \qquad \text{for } p_o = 100 \text{ GeV/c}$$

$P = 1.6 \times 10^2 I$	collisions per cm of a beam of I amperes of protons in a vacuum of 10^{-9} Torr of N_2
$P = 3.2 \times 10^3$	for 20 amperes
$\phi_\perp = 1.6 \times 10^5/$	background particles per cm^2 sec with a 20 ampere beam circulating in a vacuum of 10^{-9} Torr N_2.

II. Inelastic Scattering and Diffraction Dissociation

A diffraction process can yield an excitation of a proton (mass m_o) to an excited level (mass $m = k\, m_o$) with a change in momentum of the other proton of Δp according to

$$\frac{\Delta p}{p_o} = \frac{k^2-1}{4} \left(\frac{m_o}{p_o}\right)^2$$

$$\left(\frac{m_o}{p_o}\right)^2 = 10^{-4} \quad \text{for } p_o = 100 \text{ GeV/c}$$

Hence:

$\Delta P/p$	ΔP (GeV/c)	$-t$ $(\text{GeV/c})^2$	k
0.01	1.0	1.0	20
0.003	0.3	0.1	11
0.001	0.1	0.01	6

There are at least two conclusions which are important to note here. First, "missing mass spectroscopy" (in which the total invariant mass of one recoiling final state is deduced from precision measurements of initial and final momenta of the other proton) is totally impractical here.

Second, very massive states may be excited with only modest momentum transfers. Final states of the sort $p + X + \overline{X}$ where X is a baryon, an intermediate boson, or a quark, might be produced with sizeable cross sections even for $m_X = 3.5$ GeV.

III. Very Small Angle Elastic Scattering

The range of pp elastic scattering about momentum transfers of 5×10^{-2} GeV/c or $-t$ of 2×10^{-3} $(\text{GeV/c})^2$ are useful for studying Coulomb-nuclear interference effects from which the real part of the scattering amplitude may be found.

The proposal would be to place a matrix of detectors (e.g., solid state counters) in re-entrant, thin-walled wells supported on sylphon bellows os that they could be extended to within a cm of the circulating beam. By working in the horizontal dimension with one turn, the scattering can be accommodated in the radial space normally used for inflection, and for betatron and synchrotron stacking. Detectors would be placed 1/4 betatron wave length beyond the colliding "target" region. Two sets of detectors in each leg, corresponding to overall 4-fold coincidence, would be used. They might be spaced by a magnet block or two so as to sample separate backgrounds. The intrinsic phase space of even a one-turn beam limits the smallest scattering angle one may detect, and even one-turn beams may require clipping to reach the smallest angles of interest (~0.2 mr).

For 100 GeV colliding beams, such a momentum transfer corresponds to a scattering angle of 0.5 mr. An experiment would be designed to cover a range of from 0.2 to 1.0 mr, covering $4 \times 10^{-4} < -t < 10^{-2}$ $(\mathrm{GeV/c})^2$.

The range of cross sections relevant here are

$$\frac{d\sigma}{dt} \approx 10^{-25}\ \mathrm{cm^2/GeV/c}\ ; \quad \frac{d\sigma}{d\Omega} \approx 1.6 \times 10^{-22}\ \mathrm{cm^2/sr}$$

The total cross section inside 1 mr is

$$\sigma = \int_0^{1\ \mathrm{mr}} \frac{d\sigma}{d\Omega}\ \theta d\theta \approx 10^{-28}\ \mathrm{cm}^2$$

If only one turn of protons is injected into each ring,

$$L = 5 \times 10^{28}\ \mathrm{cm^{-2}sec^{-1}}.$$

If an apparatus subtends $\Delta\phi \approx 70^\circ$, $\frac{\Delta\phi}{2\pi} = \frac{1}{5}$

$L\sigma\Delta\phi \approx$ 1 detected scatter per second.

The background flux would be, for this one turn beam,

$$\phi_\perp = \frac{3.2 \times 10^3}{\rho}\ \frac{\mathrm{particles/cm^2sec}}{\mathrm{cm}}$$

At 0.3 cm from the circulating beam, there would be $10^4/\mathrm{cm^2sec}$. A system of solid state counters with 0.1 cm^2 per element would have an accidental rate of 10^3/sec. If the resolution were 1 μsec and a 4-fold coincidence were used, the accidental 4-fold rate would be (ideally) 10^{-6}/sec or 10^{-6} of signal.

IV. Cherenkov Counters

Threshold Cherenkov counters operated at the ambient pressure will be very useful in this energy range. Thus air at S.T.P. has a threshold γ of about 40, hydrogen gas has $\gamma_T \approx 100$, and helium has $\gamma_T \approx 140$. An air counter 3 m long should produce about 90 quanta, or about 20 photoelectrons per particle above threshold. Combinations of these counters could readily select protons or reject pions, etc. in conjunction with momentum analysis.

NOTE:

Much of the material herein is a 100 GeV adaption of considerations discussed during a 1963 BNL summer study on storage rings and reported in the proceedings of that study and at the 1963 Dubna International Conference on High Energy Accelerators: "Recent U. S. Work on Colliding Beams", p. 300, L. W. Jones.